Referee Report on “Studies of Baryonic Matter at the Nuclotron (BM@N)” Project progress and proposed continuation for 2027-2031

Theme code: 02-1-1065-2007/2026
Project code: 02-1-1065-2-2012/2026

The BM@N experiment operates as part of the Nuclotron/NICA accelerator complex, with beams varying from deuteron to Bismuth in the kinetic energy range of 1-6 AGeV onto fixed targets, allowing for higher interaction luminosity than in collider settings. Matter densities created in these heavy ion collisions are 3-4 times higher than the nuclear saturation density. The main goal of the BM@N project is to study the properties of this matter, with a focus on studying the production of strange particles near or below their production threshold in nucleon-nucleon interactions. Such studies are expected to be ultrasensitive to the equation of state, the hyperon-nucleon interactions, and the nucleonic-partonic phase transition.

The progress report described several physics achievements. The production of charged pions and kaons in Argon-nucleus interactions at 3.2 AGeV follows the world-data excitation functions, and the kaon to pion production ratio is found to be largely centrality independent [Afanasiev et al., JHEP 2023 (2023) 174]. Production of protons, deuterons and tritons in Argon-nucleus interactions at 3.2 AGeV was measured [Afanasiev et al., JHEP 2025 (2025) 95]. A Blast-Wave model was used to fit the invariant transverse mass spectra to characterize the kinetic freeze-out properties (temperature and flow velocity). It is interesting to note that the flow velocity is consistent with zero in the small Ar+C system and becomes nonzero starting with system as small as Ar+Al but remains practically the same with increasing system size. The simple coalescence model was used to extract the baryon phase-space density from baryon correlation function measurements. It is also interesting to note that the compound yield ratio of (proton*triton/deuteron^2), predicted to be sensitive to baryon density fluctuations, remains smooth as a function of the collision energy of world data.

The BM@N detector system and data acquisition are adequately described. The detector covers the full azimuth and the forward and ~midrapidity range in the longitudinal direction. It allows tracking and momentum measurement, particle identification, and overall event activity and geometry characterizations. The data acquisition system allows high-rate data taking up to approximately 10 khz.

Ongoing and planned analyses include production rate of strange mesons, (multi)-strange hyperons, protons, neutrons, light nuclear fragments, and hypernuclei, the directed and anisotropic flows of protons and deuterons, baryon-baryon femtoscopy, and hyperon polarization phenomena in heavy ion and polarized deuteron beams. These analyses will be performed in 3.2 AGeV Argon-nucleus, 3.8 AGeV Xe+CsI, and planned future collisions of other nuclear species.

To meet the challenge of high multiplicities in planned collisions of beams up to Bismuth, several expansions of the detector systems are being developed, including the central tracking system, the time-of-flight system, a new large-aperture silicon forward detector station, a high-

granularity time-of-flight neutron detector, deuteron beam scintillation detectors for the hyperon polarization program, and upgrade of the online farm.

Uncertainties and risks of the proposed continuation of BM@N are reasonably assessed, including possible delays/slides from a prolonged commissioning of the NICA collider. The requested budget is justified for the scope of the project and is in line with the norm.

The NICA collider and the general-purpose experiment in the collider mode are undoubtedly the future focus of JINR. To have a fixed-target experiment running, gaining real-field experience, and producing relevant physics is extremely important and valuable side-by-side to the collider experimentation, involving largely overlapping personnel.

In conclusion, BM@N has produced and is producing interesting physics pertaining to the nuclear matter phase diagram, the central theme of the broad nuclear physics field including the NICA collider. It has a clear vision of the physics programs in the next few years and has a well-defined plan for detector upgrades to meet this vision. BM@N is an international collaboration, but JINR is clearly the backbone of the experiment. I recommend the continuation of the BM@N program in 2027-2031 with the first priority.

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December 6, 2025